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On Aluminium Bronze as a Material for the Construction of Astronomical and other Philosophical Instruments. By Lieut.-Colonel A. Strange, F.R.A.S.

The author, after referring to the Astronomical and Geodesical instruments about to be constructed, under his superintendence, by order of the Government, for the use of the Great Trigonometrical Survey of India, and after noticing that one of the points which has given him most anxiety had been the selection of the proper material or materials of which to construct these instruments, and that his present remarks were confined to the great Theodolite with a horizontal circle 3 feet in diameter, and after detailing the requirements of such an instrument, proceeds as follows:—

"Such then was the problem presented for solution: to construct an instrument with extended powers, and cast as much as possible in masses, the transportation of which, over the most difficult ground, should not be beyond the power of human labour.

"When on the point of compromising the difficulty by separating, so as to form distinct packages, parts hitherto regarded as inseparable, my attention was attracted by the various articles made of 'Aluminium Bronze' sent to the International Exhibition by Messrs. Bell Brothers, of Newcastle, and M. Morin, of Paris. The inquiries I made in various quarters satisfied me that this metal possessed most valuable qualities, but I failed in my endeavours to obtain reliable numerical data for comparing it with other metals. I therefore instituted experiments on it, the results of which I beg now to communicate to the Society.

"The alloy called Aluminium Bronze was first, I believe, made by Dr. Percy five or six years ago, and is composed of Aluminium and Copper in various proportions, 10 per cent of Aluminium, however, giving the best material for mechanical purposes.

"The qualities of most importance in instrument making are, (1) Tensile strength; (2) Resistance to compression; (3) Malleability; (4) Transverse strength or rigidity; (5) Expansive ratio; (6) Founding qualities; (7) Behaviour under files, cutting tools, &c.; (8) Resistance to atmospheric influences; (9) Fitness to receive graduation; (10) Elasticity; (11) Fitness for being made into tubes; (12) Specific gravity.

"Of these, tensile strength, resistance to compression, and malleability, were most obligingly tested for me by Mr. Anderson at the Royal Gun Factory, Woolwich; and the other qualities by Messrs. Simms, by whom the great Theodolite is now being constructed. I will take the above enumerated properties in their order, premising that to have obtained results of an absolute and final character would have involved more time than I could spare, and that therefore those which follow, though sufficiently reliable for almost any practical

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purpose, are open to the correction of more extensive experiments.

"(1) *Tensile strength.* This was tried some years ago by Mr. Anderson with the following results. Breaking strain

Aluminium bronze . . .	95,747	lbs. per square inch.
Gun metal	32,000	

"Mr. Anderson was good enough to try it again for me in September last, and states in his report, 'The average tenacity of this metal proved to be 22 tons 12 cwt. (50,624 lbs.) breaking weight per square inch in the two specimens tested; elongations did not take place until 4300 lbs. in the one case, and 3600 lbs. in the other, had been applied, when a permanent elongation was noticed of ·009 of an inch in the first specimen, and ·034 of an inch in the last.' Mr. Anderson adds that the specimens were not quite sound.

"In the above cited report Mr. Anderson gives a higher tensile strength to gun metal than before, namely, 17 tons (38,080 lbs.) for the average of the '*best specimens*' tested at the gun-factories.

"Combining the results we have the average breaking tensile strength of the two metals as follows:—

$$\left.\begin{array}{ll} \text{Aluminium bronze} & \dfrac{95747 + 50624}{2} = 73{,}185 \\[2ex] \text{Gun-metal} & \dfrac{32000 + 38080}{2} = 35{,}040 \end{array}\right\} \text{lbs. per square inch.}$$

the ratio being 1 to 0·48, or rather more than 2 to 1 in favour of aluminium bronze.

"For the purpose of comparing the tenacity of the new alloy with steel, we have data given by Mr. Anderson in a lecture[*] on Materials for Rifled Cannon, in which he states that cast steel varies in tensile strength from 114,000 to 67,000 lbs. per square inch; but he objects to the higher qualities as liable to brittleness, and prefers, where great strains are in question, an average quality of cast steel breaking at 80,000 lbs.; and he adds, that specimens from a gun made of Krupp's famous cast steel, characterised by 'softness' (which Mr. Anderson considers favourable to tenacity) and 'perfect soundness,' gave 72,000 lbs. per square inch, which we see is 1185 lbs. less than the average strength of aluminium bronze above given.

"(2) *Resistance to Compression.* Mr. Anderson reports on this as follows:—

"'The ultimate amount of compression applied was 59 tons, 2 cwt. 1 qr. 4 lbs. (132,416 lbs.), under which the specimen[†]

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[*] Published in No. XXIII. *Journal*, Royal United Service Institution.

[†] "The specimen subjected to this enormous pressure, distorted though it is, does not exhibit the trace of a fissure. The cohesion of its particles is inviolate."

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became too much distorted to permit of more weight being applied with any true result. Compression was not perceptible until 9 tons, 2 cwt. per square inch (20,384 lbs.) was applied, when the specimen suddenly gave to the extent of ·006 of an inch, and on the weight being removed an elasticity of ·001 was observed, which gives the first permanent compression as ·005 of an inch.'

"The compressive strength of cast iron varies a good deal. That of 'Carron Iron, No. 3,' the highest given in Ure's *Dictionary of the Arts*, is 115,542 lbs. per square inch; but it is difficult to compare in this respect two metals whose behaviour under compression is so different, cast iron yielding suddenly and almost totally, and the new alloy more gradually and partially. Astronomical instruments, however, are more dependent on the rigidity or resistance to a transverse force than to any other quality.

"(3) *Malleability.* Mr. Anderson states on this head:—

"'The qualities of this metal for forging purposes would appear to be excellent; with the exception of the part heated to a red heat in the shade, all show that it is a good workable material under the hammer almost up to melting point.'

"I may add that there were specimens in the Exhibition, showing that the alloy could be drawn out under the hammer almost to a needle point.

"I come now to the experiments tried by Messrs. Simms.

"(4) *Transverse strength.* As the absolute determination of the force necessary to break or permanently bend a bar of metal was beyond our appliances, I begged Messrs. Simms to be satisfied with a comparative value of the rigidity of the new alloy; that is, to ascertain the relative resistances of gun metal, brass, and aluminium bronze, to a force insufficient to produce permanent flexure. This they succeeded in doing, and report as follows:—

"'The same weight applied to three bars altered the index of our instrument as under,

Brass	2·22 divisions
Gun metal	0·15 ,,
Aluminium bronze	0·05 ,,

"Hence, aluminium bronze would appear to be 3 times more rigid than gun metal, and upwards of 44 times more rigid than brass.

"(5) *Expansive ratio.* This determination was also a comparative one. Messrs. Simms found that 'aluminium bronze is less affected by change of temperature than either gun metal or brass, (a little less than gun metal, and much less than brass).'

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"(6) *Founding qualities.* Regarding this there is ample experience. The alloy produces admirable castings of any size.

"(7) *Behaviour under files, cutting tools, &c.* In this respect, also, it leaves nothing to be desired. It does not clog the file; and in the lathe and planing machine the tool removes long elastic shavings, leaving a fine bright, smooth surface. Messrs. Simms state,—

"'It can be worked with much less difficulty than steel, and we should think that screws made of it would (notwithstanding the original great cost of the metal) prove in the end less expensive than screws made of steel.'

"(8) *Resistance to atmospheric influences.* Messrs. Simms state, 'it does not readily tarnish.' This, likewise, is entirely a relative question. Absolute inoxidizability, however desirable, is hardly to be expected. Suffice it, that the new alloy tarnishes much less readily than any metal usually employed for astronomical instruments, viz., gun metal, brass, silver, cast-iron, or steel.

"(9) *Fitness to receive graduation.* Messrs. Simms state, 'Aluminium bronze takes a fine division, and it will not be necessary to inlay another metal, as is usually done, to receive the graduation.' This opinion is fully justified by the specimen of graduation executed by Messrs. Simms, the lines of which are remarkably pure and equable, characteristics never presented, in the same degree, they inform me, by lines cut on any other *cast* metal. May not this superiority indicate that the alloy in question is peculiarly homogeneous? The lines are very distinct under the microscope, notwithstanding the yellow colour of the metal.

"(10) *Elasticity.* I possess no direct experiments bearing on this point. But that the alloy has considerable elasticity is unquestionable. I may here state that an eminent Parisian Instrument-maker informed me that of all the wires tried for the suspension of Foucault's Pendulum for illustrating the rotation of the earth, none, not even those of steel, were so durable under that severe ordeal as wires made of aluminium bronze. It would appear, therefore, to be the most proper material for the suspension springs of clock pendulums.

"(11) *Fitness for being made into tubes.* It admits of every process necessary for this purpose. It can be soldered with either silver or brass solder; it can be rolled into sheet metal; and it can be hammered and drawn. Hitherto telescope tubes, the cones of transit axes, the pillars of altazimuths, &c., have been made almost exclusively of yellow brass, a metal very deficient in rigidity. Gun metal does not admit of being rolled, and has therefore never been used for the tubular parts of instruments, for which the new alloy seems pre-eminently suitable.

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"(12) *Specific gravity.* The specific gravities of alloys of aluminium and copper, as determined by Messrs. Bell, are

3 per cent. of aluminium	8·691
4 ,, ,,	8·621
5 ,, ,,	8·369
10 ,, ,,	7·689

The last named, which is the best for the purposes now under notice, is very nearly the same as that of wrought iron, and less than that of either brass or gun metal.

"It appears from these experiments, and from the concurrent testimony of those who have given it a fair trial, that the 10 per cent Aluminium Bronze is far superior, not in one or some, but in every respect, to any metal hitherto used for the construction of Philosophical Apparatus, and that for such purposes it may be employed in the dimensions that would be proper in the case of cast steel. All parts which otherwise would be made of steel may, with perfect safety, and even with advantage, be made of the new alloy, particularly such parts as bolts, and fixing, tangent, and micrometer screws. Its hardness and comparative inoxidizability point it out as peculiarly adapted for pivots, axes, and bearings. If employed for receiving the graduation of circles, the necessity for inlaying another metal will be obviated, by which two advantages will be gained; the hammering which forms part of the operation of inlaying, and which, more or less, must cause unequal density and tension in the circle subjected to such treatment, will be dispensed with; and the effect of inequality of expansion in the circle and the inlaid strip will no longer be a cause of apprehension. With respect to the due visibility of divisions cut on this metal, opinions will perhaps differ. I can only say that I should be well content to observe with them.

"The use of this alloy for the construction of the new Great Theodolite is, in the opinion of Messrs. Simms, and in my own, fully justified by what we now know of it; and the effect of using it will be to keep the weight of the instrument within reasonable limits, notwithstanding its possession of means and appliances not hitherto bestowed on such instruments.

"Two points remain; the making of the alloy, and its cost.

"The metal Aluminium is at present extracted in England by one firm only, Messrs. Bell Brothers, Newcastle, under a license from M. Deville, the French discoverer of the process. I have met with instances of failure in making the alloy with Copper. Two main points only, however, seem to require particular attention. First, extremely pure copper must be used. The best is copper deposited by electricity, but that kind is very expensive; the next best is copper from Lake Superior, which makes an alloy of excellent quality. The ordinary coppers of commerce generally fail, owing, it is said,

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chiefly to the presence of iron, which appears to be specially prejudicial. The second precaution is to re-melt the alloy two or three times. The first melting of 10 aluminium and 90 copper produces an alloy of excessive brittleness. Each successive melting, up to a certain point determined by the working, and particularly the forging, properties of the metal, improves its tenacity and strength. It is probable that after several meltings there will remain in combination with the copper a somewhat smaller proportion of aluminium than 10 per cent.

"The present price of the English made 10 per cent. Aluminium Bronze is 6*s*. 6*d*. per lb., but there is reason to believe that, as the process of extracting the aluminium becomes more largely practised, and the demand for the metal increases, the price will fall. The above price is four or five times that of gun metal. A much smaller quantity, however, of the new alloy than of gun metal will give the same strength; and when it is considered how small a ratio the cost of the material bears to the cost of workmanship in refined apparatus, it will be found that even at the present price of the new alloy its cost is not prohibitory, whilst the advantages attending its use promise to outweigh the increased expenditure.

"In the foregoing paper, which I am aware is very imperfect and incomplete, I have sought no more than to contribute such an instalment of practical information regarding this remarkable material as may be of service to those, who, like myself, contemplate making use of it, of whom I trust there will be many, for by its use we shall, I venture to think, confer on such structures at once greater strength and less weight, and so diminish tension, flexure, and distortion, to an extent calculated sensibly to improve the higher order of instruments of physical research.

On the Solar Energy as manifested in the Autumn of 1861 *and a Portion of the Spring of* 1862. By W. R. Birt, Esq.

During the summer of 1860, both previous to and in connexion with the great outburst of solar energy, that occurred towards the end of June in that year, I noticed a very marked monthly maximum and minimum of solar spots; and while there existed indications of an intermittent action of the solar force, I was satisfied that the maxima and minima I had frequently noticed were dependent on the rotation of the Sun.

Regarding each group of spots, single spots, if unattended by smaller ones, or separate nuclei if they were sufficiently distinct to warrant the appellation, as centres of energy, I laid